Development of a Low Charge-to-Mass Ratio Post Accelerator for RIA

R&D Category:
Post Acceleration

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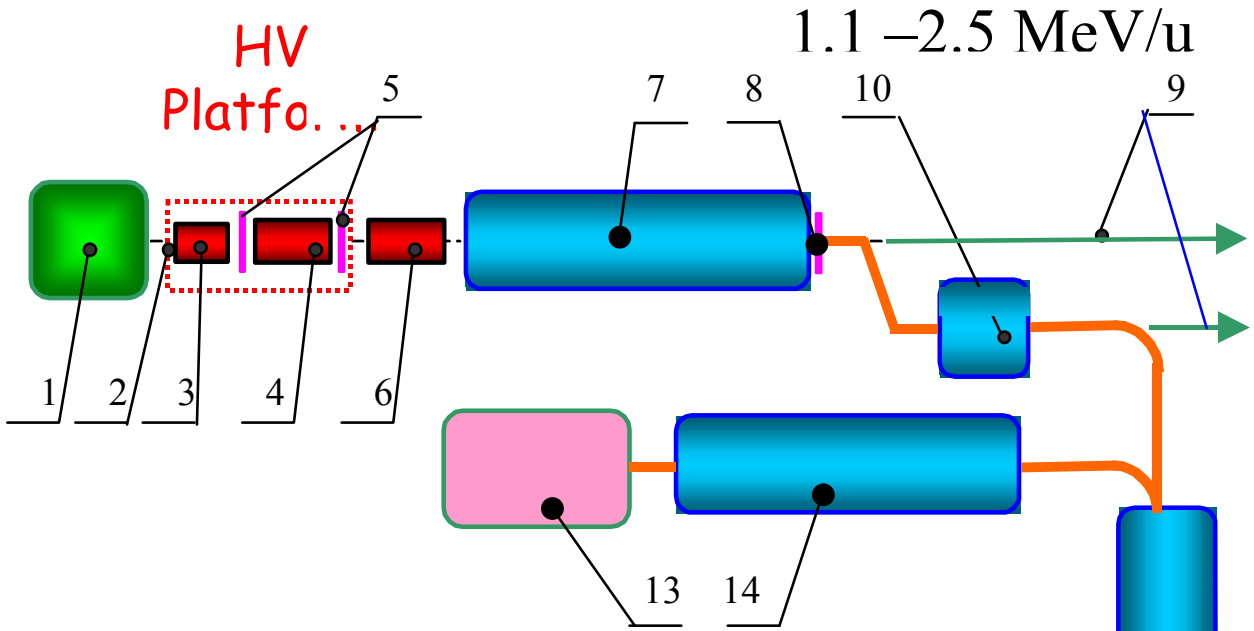
RIB linac

The rare-isotope post-accelerator will be called upon to deliver a wide variety of beams to a wide variety of users. To summarize the demands placed on this element of RIA, it must:

- Provide continuously variable output beam energy.
- Accelerate the full mass range of ions to energies above the Coulomb barrier.
- Provide state-of-the-art beam quality.
- Exhibit high overall efficiency and maximize beam current.
- Accept ions of low charge state.

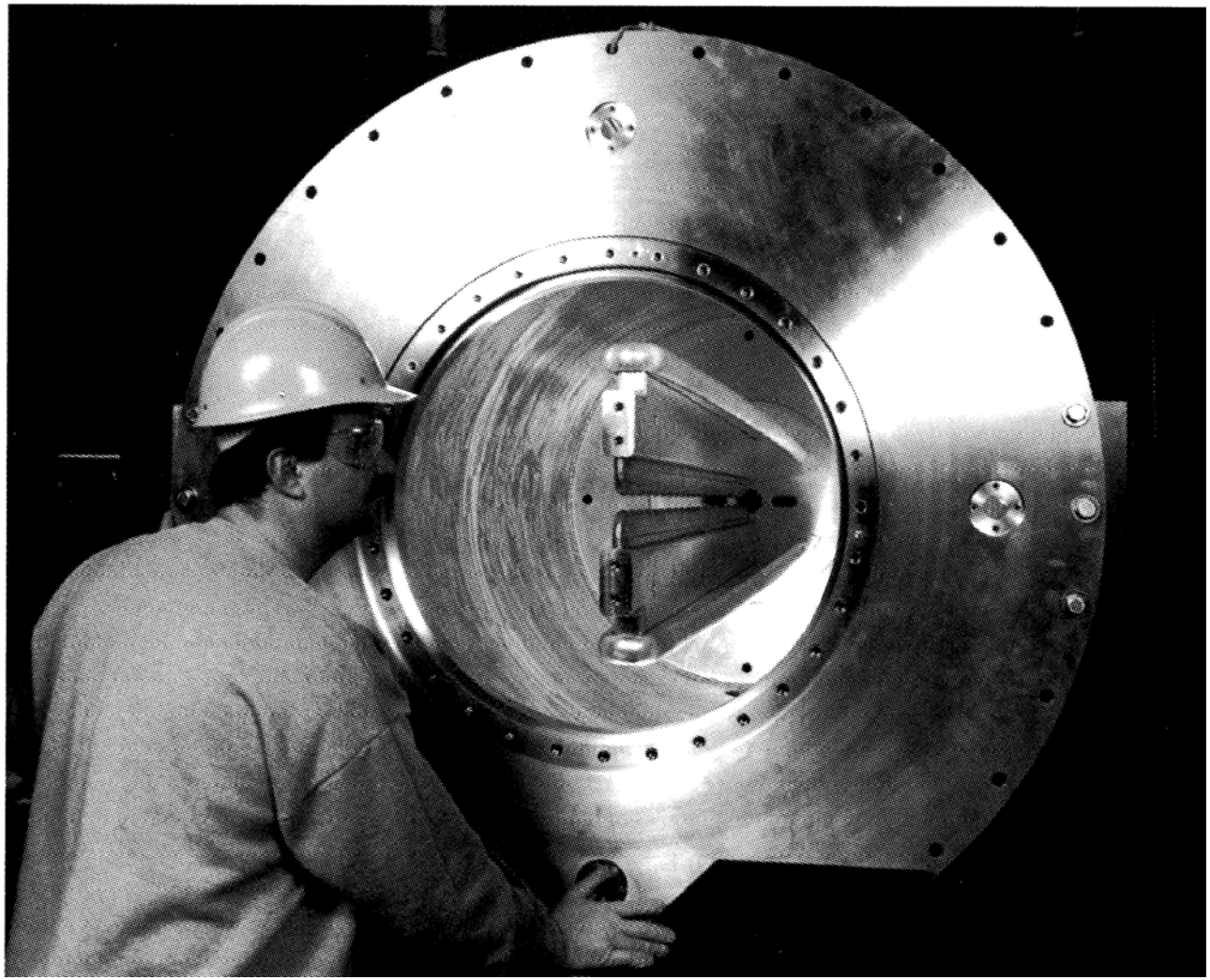
RIB linac



1 – Isobar separator, 2 – High voltage platform,
3 - 12 MHz RFQ, 4 – 12 MHz Hybrid RFQ,
5 – helium strippers, 6 - 24 MHz Hybrid RFQ,
7 – SC Linac between the strippers,
8 – carbon stripper, 9 – beams to astrophysics experiments, 10 – SC booster linac,
11 – upgraded ATLAS, 12 – high energy beams,
13 – charge breeder, 14 - PII.

One of Two Vane Pairs of the Split-Coaxial 12 MHz RFQ*

$^{132}Xe^{+1}$

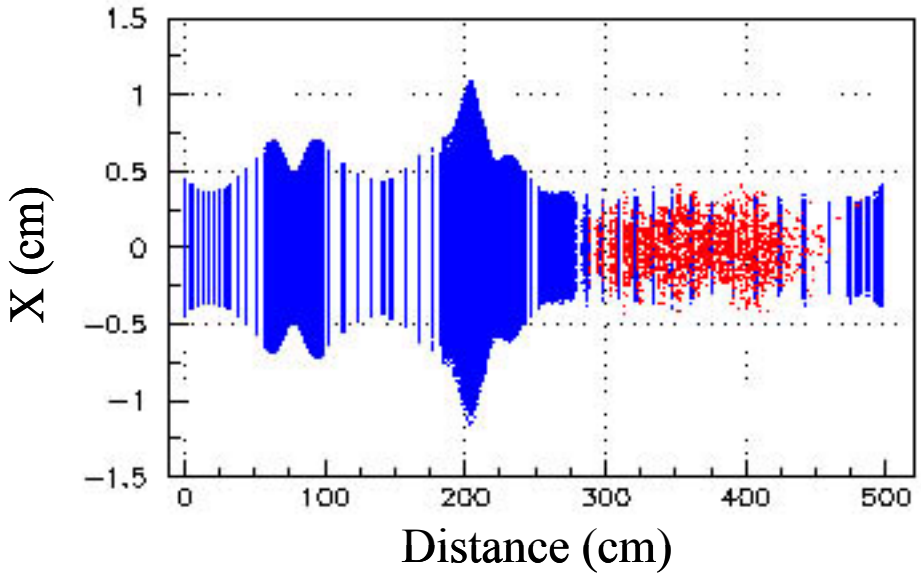


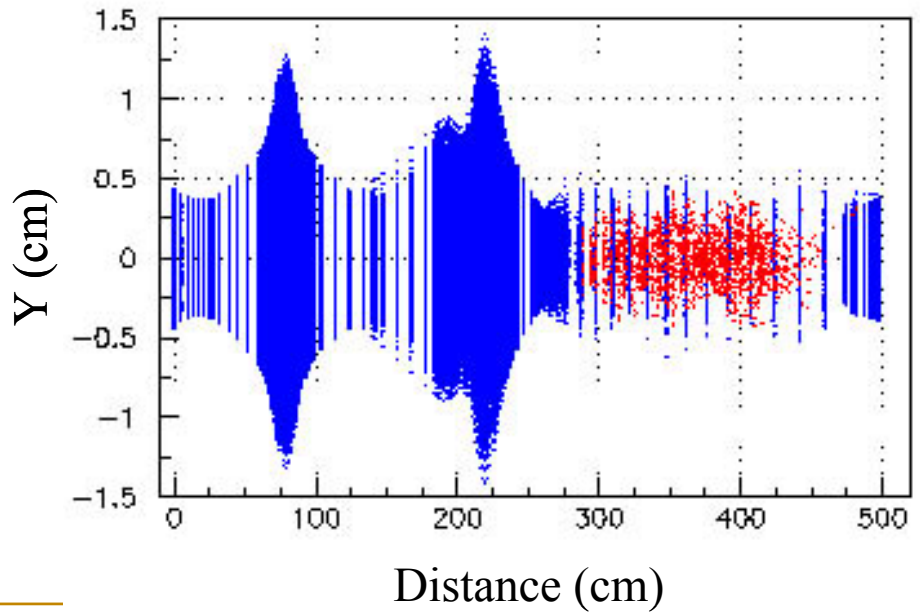
*See K. Shepard et al. LINAC1996, PAC1997, PAC2001.

Design parameters of the RFQ for acceleration of $^{240}U^{+1}$

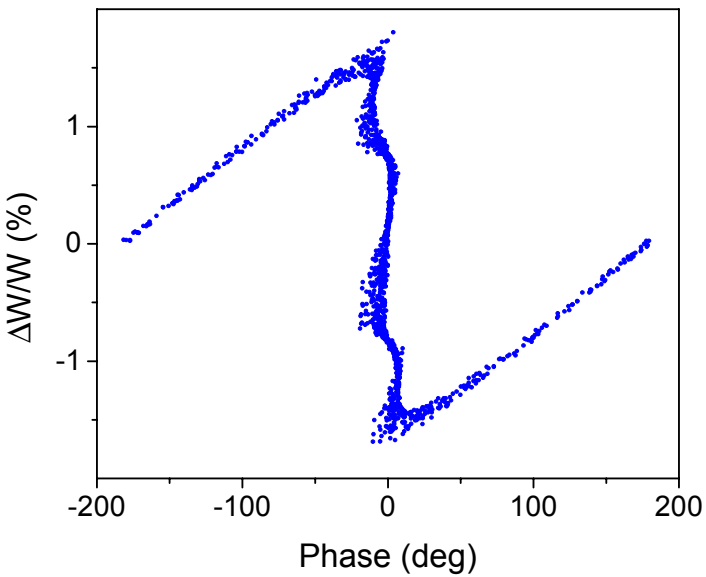
Operating Frequency	12.125 MHz
Charge to Mass Ratio	1/240
Input Energy	2.0 keV/u
Output Energy	7.12 keV/u
Inter-Vane Voltage	92 kV
Average Distance Between Opposite Electrodes	18 mm
Relative Electrode Thickness	0.75 R_0
Maximum Electric Field	128 kV/cm (1.25 Kp units)
Modulation	1.3 ÷ 1.9
Synchronous Phase	-25°
Number of Cells	57
Length	2.2 m
Phase Advance of Transverse Oscillations	19°
Transverse Normalized Acceptance	0.4 π·mm·mrad

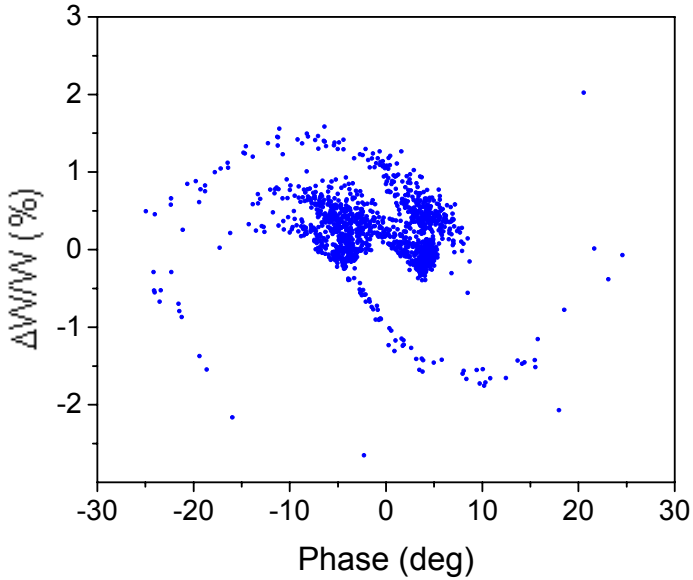
Beam envelopes along the MHB and 12.125 MHz RFQ

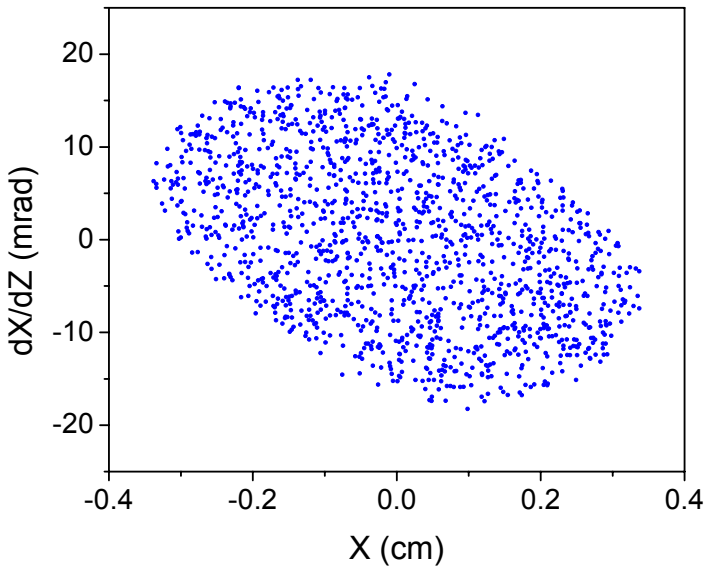


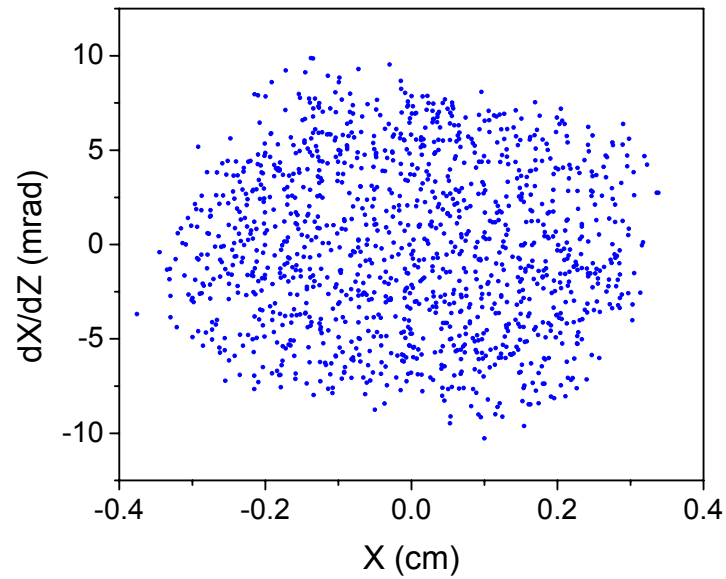


Phase space plots in the RFQ



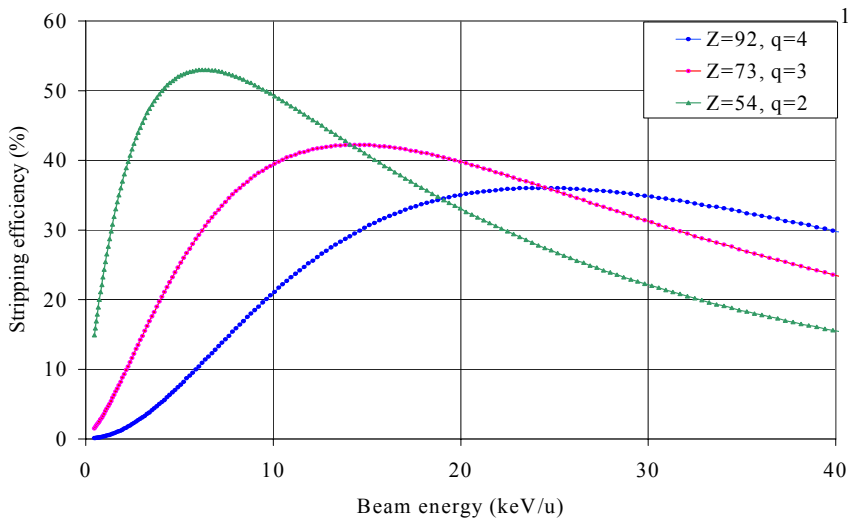


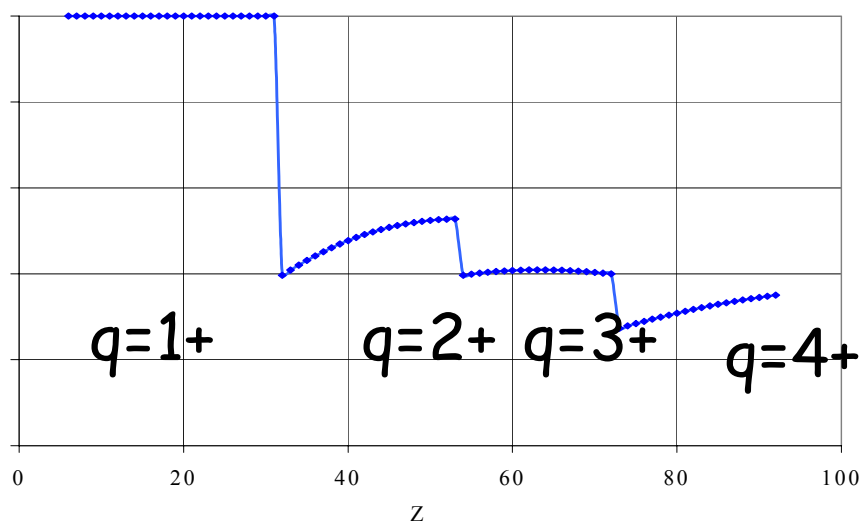




Helium stripping efficiency

Goal: to produce ions with charge-to-mass ratio ≥ 1/66





Accelerating structure for the Hybrid-RFQ, f=12.125 MHz

$^{240}U^{+1}$

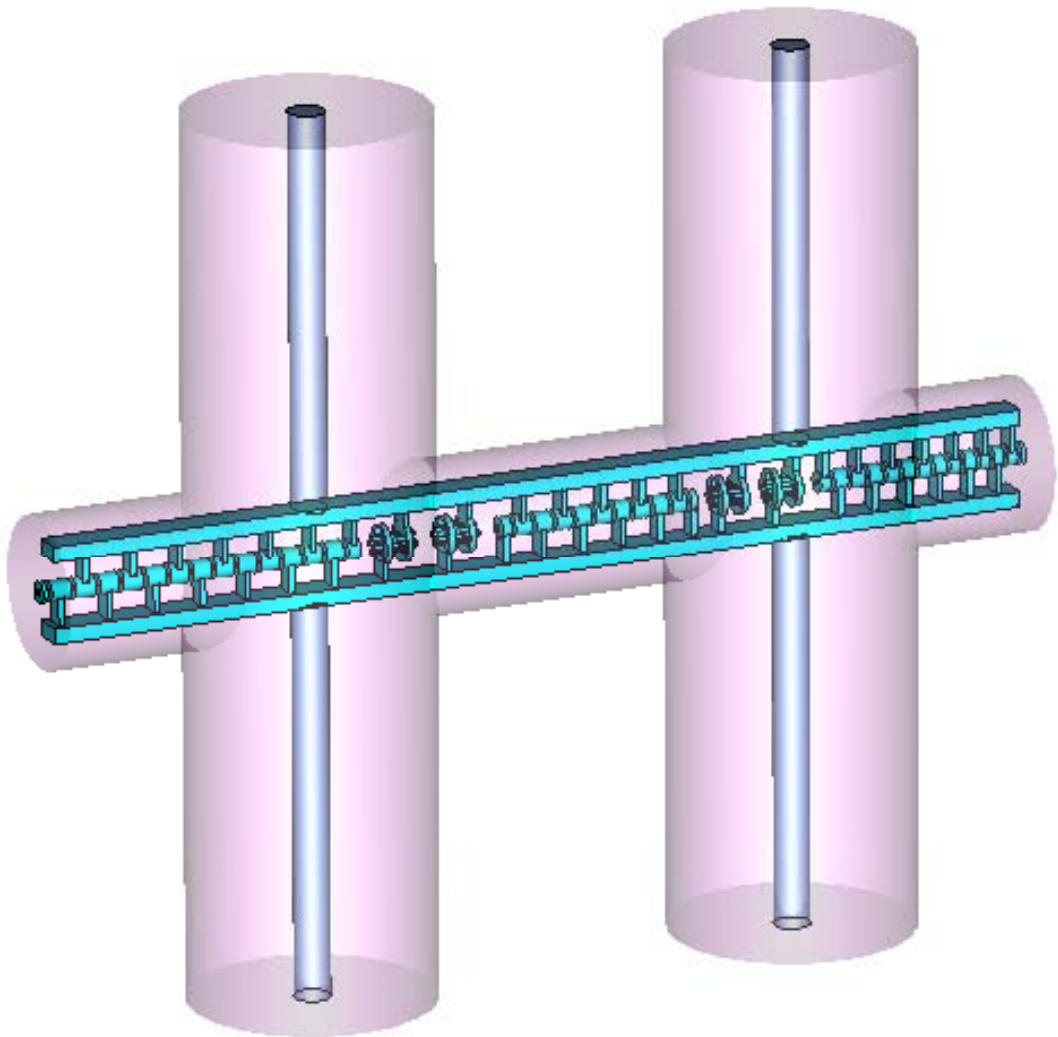
V=100 kV

$P_{calculated}$=11 kW

L=3.5 m

W_{inj}= 7 keV/u

W_{exit}=22 keV/u

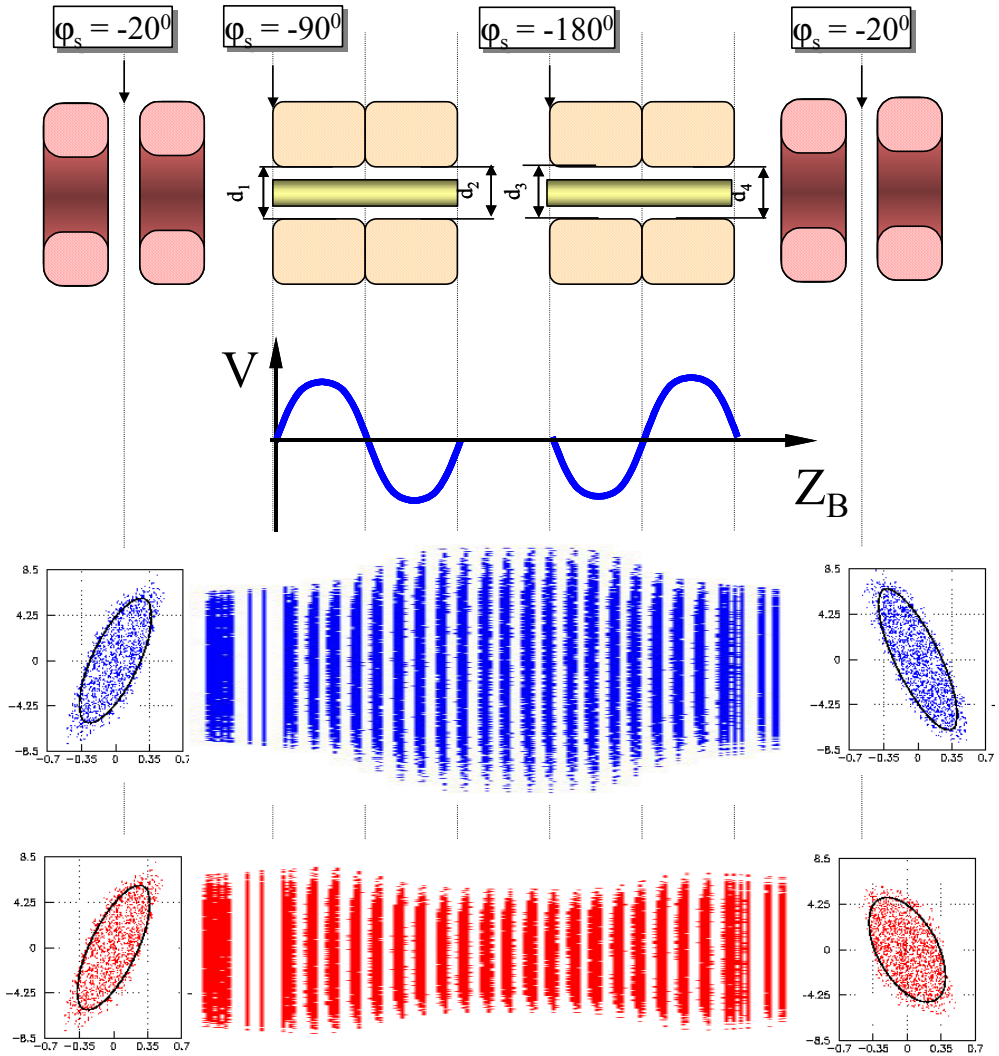


Basic Parameters of the H-RFQ-1

Operating Frequency	12.125 MHz
Charge to Mass Ratio	1/6-1/240
Input Energy	7.12 keV/u
Output Energy	20.3 keV/u
Inter-Vane Voltage	100 kV
RFQ aperture radius	1.14-1.23 cm
Maximum Electric Field	118 kV/cm (1.18 Kp units)
Clear bore diameter	20 mm
Number of drift tubes in three sections	13-10-13
Length	3.34 m
Transverse Normalized Acceptance	0.3 π·mm·mrad
Resonator quality factor	10800
RF power according to the code CST MWS	11.6 kW

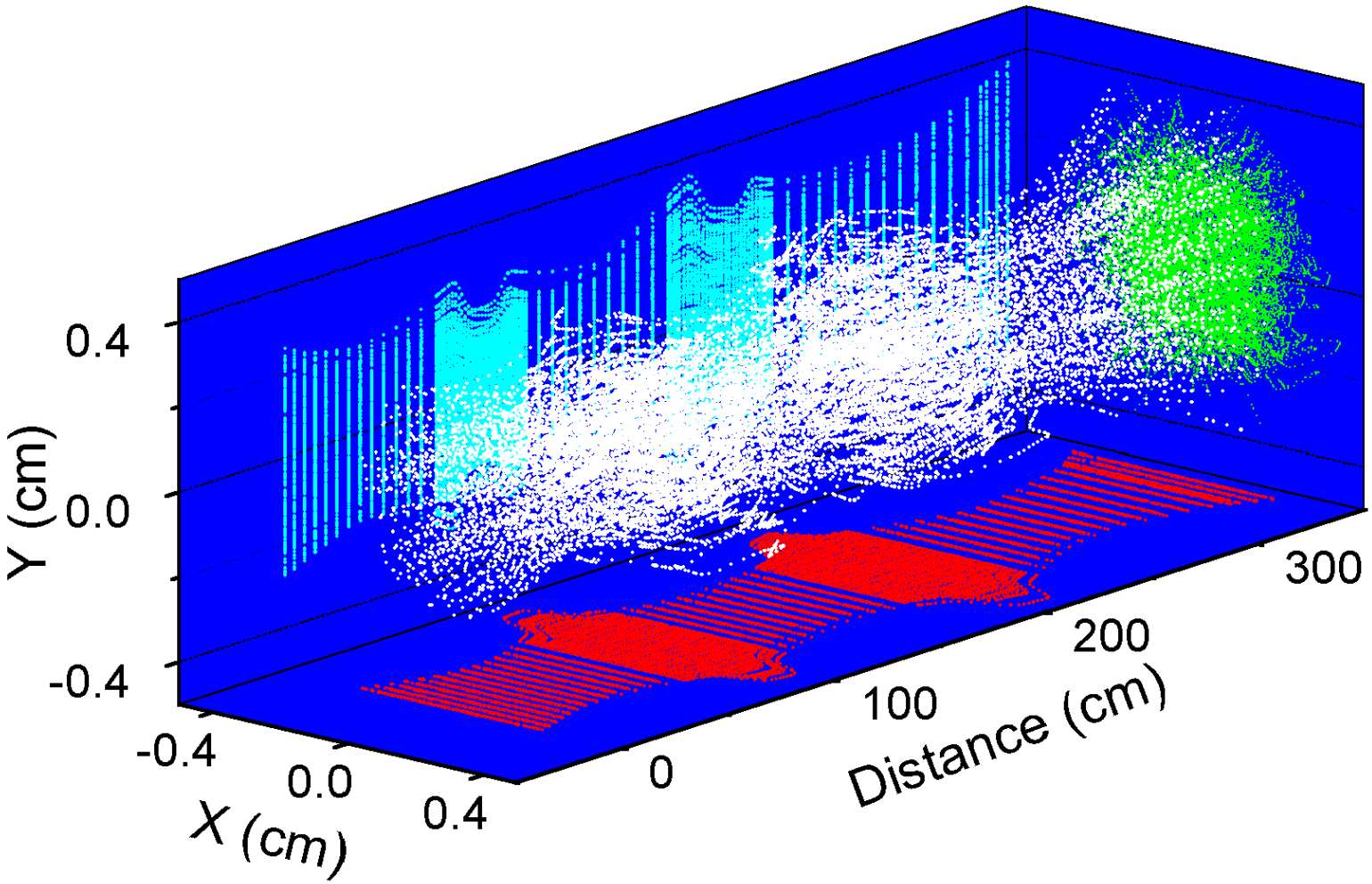
Focusing by rf Quadrupole

L= 5 $\beta\lambda/2$

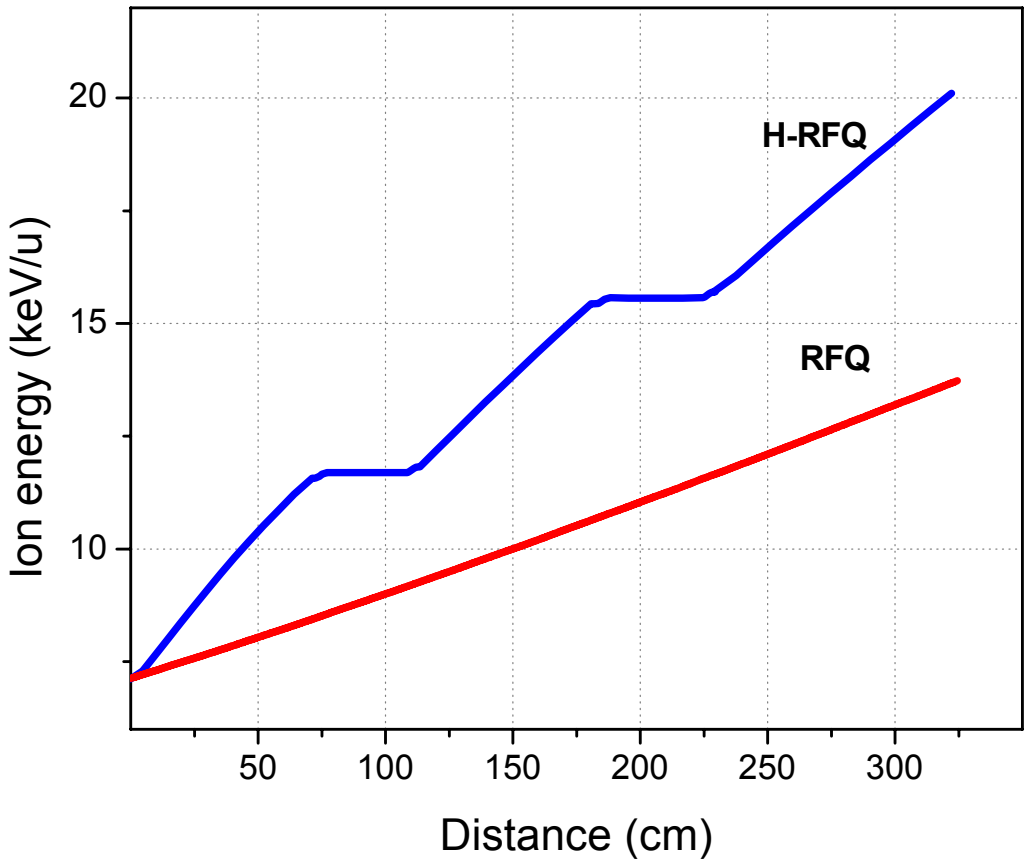


Results of simulation by the DINAMION code

Particle trajectories in real space

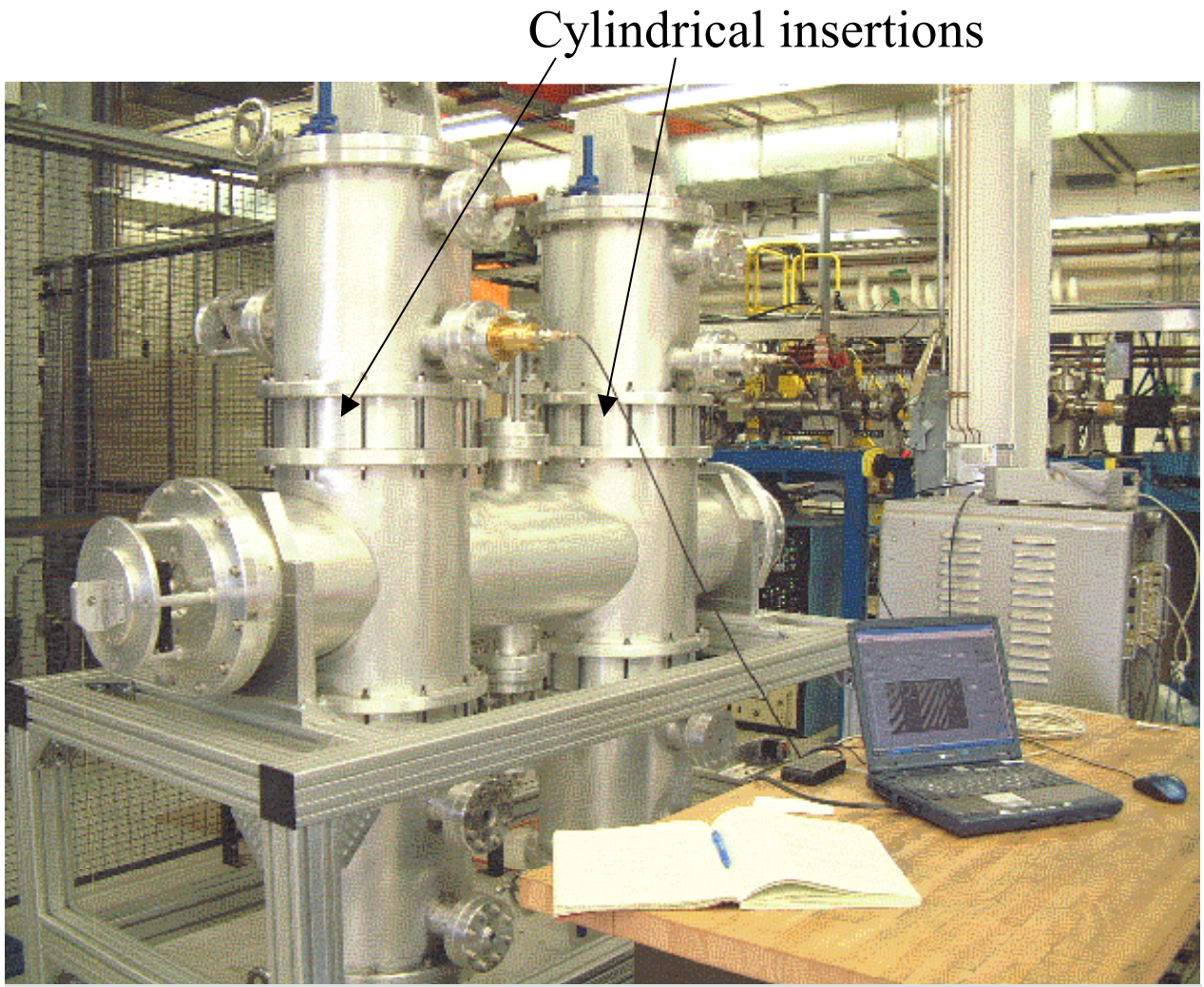


Beam energy gain in H-RFQ and in conventional RFQ. The structures have the same voltage between electrodes.



1:2 Model of the 12 MHz Hybrid RFQ

N. Vinogradov's talk



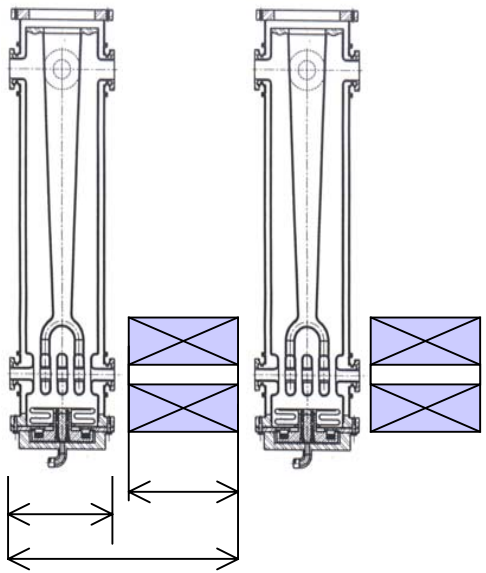
SC elements of the RIB linac

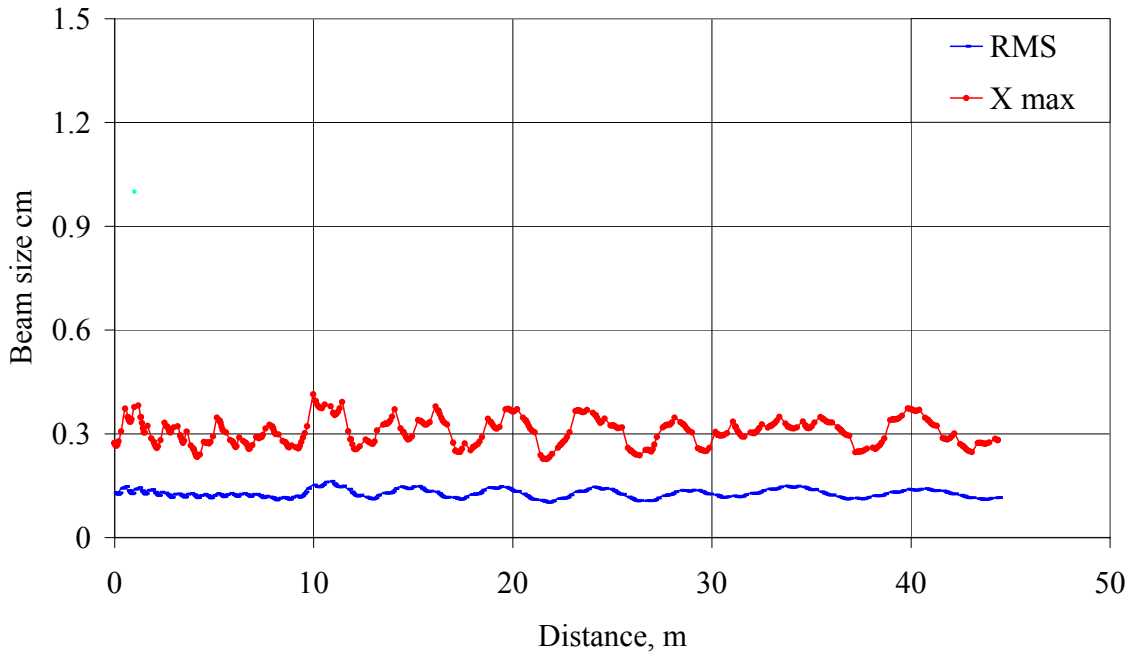
Peak surface field = 20 MV/m

Beta	0.0172	0.026	0.0389	0.0763	0.065	0.105	0.141
f, MHz	48.5	48.5	72.75	72.75	97	97	109.125
# of res.	12	16	30	6	12	24	16
Vgain, MV	0.9	1.38	1.44	1.12	0.71	1.07	1.54

K.W. Shepard, July 2003

RIB linac beam dynamics, q/A=1/66

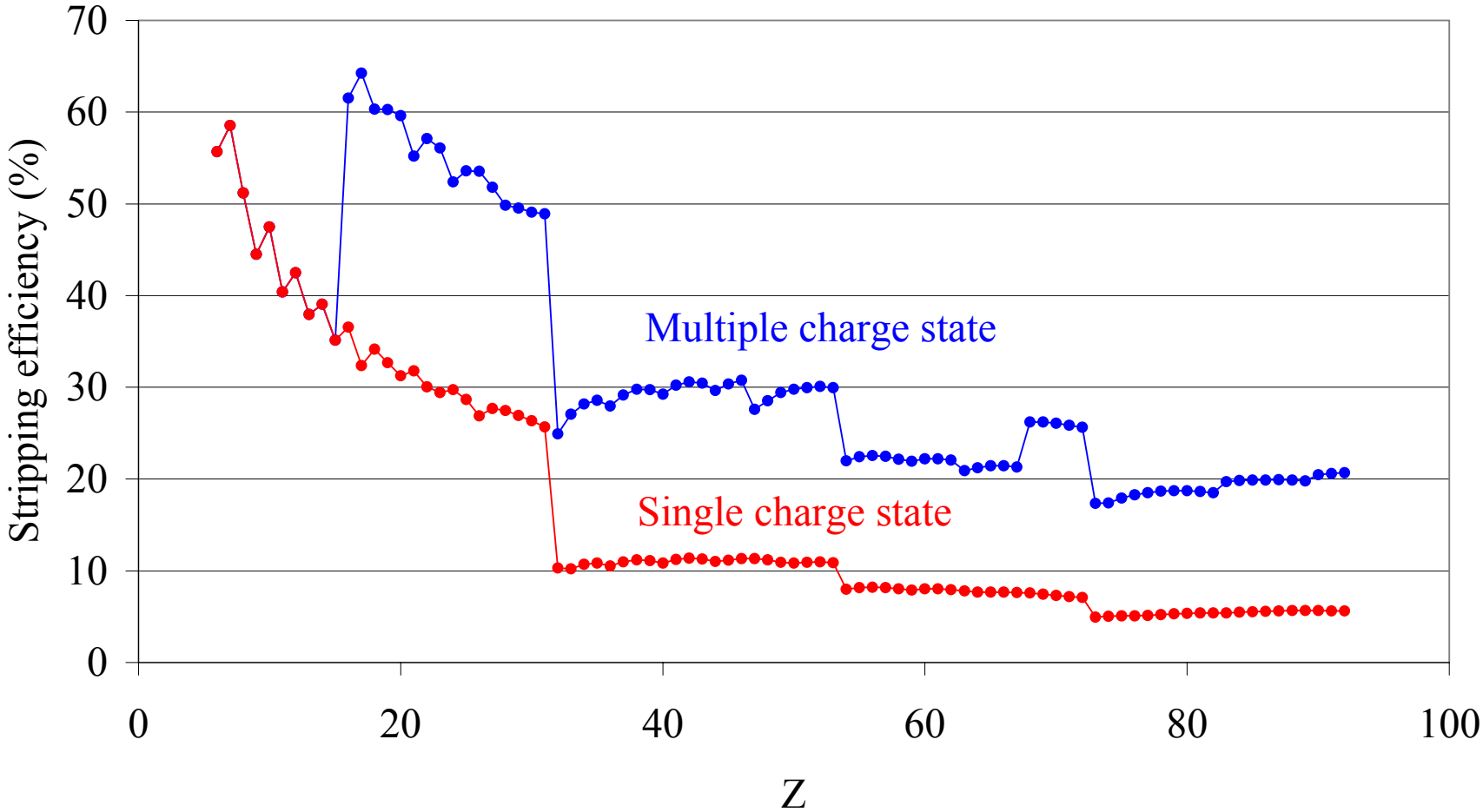




Longitudinal acceptance

Cavity beta	Acceptance
$\beta_G = 0.015$	2.0 π·keV/u·nsec
$\beta_G = 0.025$	4.5 π·keV/u·nsec
$\beta_G = 0.037$	5.7 π·keV/u·nsec

Overall efficiency of the RIB linac



Summary

- Low charge-to-mass ratio post-accelerator is technically feasible;
- RIA post-accelerator will have high acceleration efficiency for all masses;

Needs for future work

- Prototype 12 MHz Hybrid RFQ. Test with rf power up to q/A=1/240, test with beam for q/A=1/132.
- Prototype 15 Tesla solenoids together with SC resonator;
- Study of cost-effective focusing methods for low q/A heavy-ion beams.
- Beams optics studies to minimize the emittance growth of multiple charge state radioactive beams after the second stripper.